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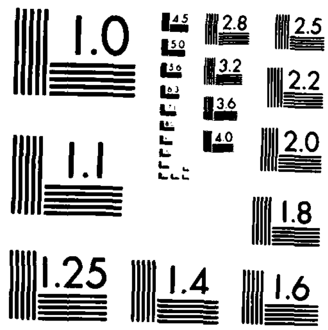
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Report 2417

EVALUATION OF EVAPORATION LOSS OF CHLOROTRIFLUOROETHYLENE FLUID IN AN M60 HYDRAULIC FLUID RESERVOIR

December 1984

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Belvoir R&D Center
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Evaporation	Volatility	MIL-H-6083 (OHT)	Chlorotrifluoroethylene (CTFE)
Semi-opened system	Hydraulic fluid	Non-flammable hydraulic fluid	M60 hydraulic fluid reservoir
Open system	Closed system	TGA	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this study was to evaluate the potential volatility problem of Chlorotrifluoroethylene (CTFE) fluids if used in the existing hydraulic systems of armored vehicles. Laboratory simulated service evaporation tests were conducted using the actual M60 hydraulic fluid reservoir at 160 °F for 3 wk and an additional 3 wk at 200 °F. The fluids used in these tests were the petroleum-based MIL-H-6083 (OHT) which was selected as the reference fluid and the experimental CTFE fluid which has been chosen as the candidate base material for the non-flammable hydraulic fluid currently under development. The test results showed negligible evaporation loss in both fluids under the conditions of the test performed. Therefore, it is concluded that volatility should not present any problem in the future use of CTFE-base fluids in the existing hydraulic systems.

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TABLES

EVALUATION OF EVAPORATION LOSS OF CHLOROTRIFLUOROETHYLENE IN AN M60 HYDRAULIC FLUID RESERVOIR

I. INTRODUCTION

The U.S. Army has used a petroleum-based hydraulic fluid covered by Military Specification MIL-H-6083 (OHT) as a standard operational fluid in all Army ground equipment.[1] During the Middle East conflict of 1973, the OHT fluid caused severe flammability problems in armored vehicles. As an interim solution, the Army developed and subsequently issued a new Military Specification MIL-H-46170 (FRH) to reduce the overall fire threat problem in armored vehicles.[2] Since the fielding of the FRH fluid was only an interim solution, as it is slightly less flammable than the OHT fluid, a program was initiated within the Army to address the development of a non-flammable hydraulic fluid for use in all Army armored vehicles.[3]

Preliminary investigations have focused on the halocarbon-based hydraulic fluid which has no flash or fire point. This fluid is a blend of completely halogenated chlorotrifluoroethylene (CTFE) oligomers and is completely inert to all acids, alkalis, and oxidizing agents. In earlier studies, laboratory screening tests were conducted according to an ASTM method[4] and Thermogravimetric Analysis method (TGA) to assess the high volatility and its potential for problems with use of this candidate hydraulic fluid. Since both test results confirmed that the candidate fluid blend is very volatile, simulated service evaporation tests were conducted to define the extent of this problem using specific components obtained from the existing hydraulic system. These tests were conducted at 160 °F for 3 wk followed by an additional 3 wk at 200 °F using a modified hydraulic fluid reservoir from an M60 A3 main battle tank.

The hydraulic fluids used in these tests were CTFE and OHT fluids. The OHT fluid was used as the reference fluid in this investigation because this fluid has been used successfully for many decades without a major evaporation problem in the field, while also indicating high volatility in the previously mentioned ASTM D972 and TGA tests.

Finally, this report describes the findings and the results of the simulated service evaporation tests.

II. TEST DETAILS

The simulated service evaporation test apparatus is shown in the figure on the following page. The apparatus consists of an M60 hydraulic fluid reservoir, a stirrer, a temperature monitor, a thermocouple well, a dip-stick gage, a support plate for reservoir, and a constant-high-temperature silicone oil bath. The M60 hydraulic fluid reservoir was chosen for use because of its capacity (about 4 gal). Additionally, the M60 tank is commonly used in the Army. For the purpose of this study, several modifications were made to the reservoir. The bottom of the reservoir was welded closed instead of being attached to the hydraulic pump. The top of the reservoir was sealed with a cover in lieu of being attached to the hydraulic riser assembly. A high-speed stirrer (3200 r/min) was mounted on the cover to simulate the turbulent flow and surface agitation normally generated by the hydraulic pump. For testing, the modified reservoir was placed in a silicone oil bath with a support plate as shown in the figure. The test temperature was maintained by the silicone oil bath and was regulated by the electronic temperature monitor. The fluid level in the reservoir was measured by use of a dip-stick gage calibrated with 1/16-in increments to show volume capacity.

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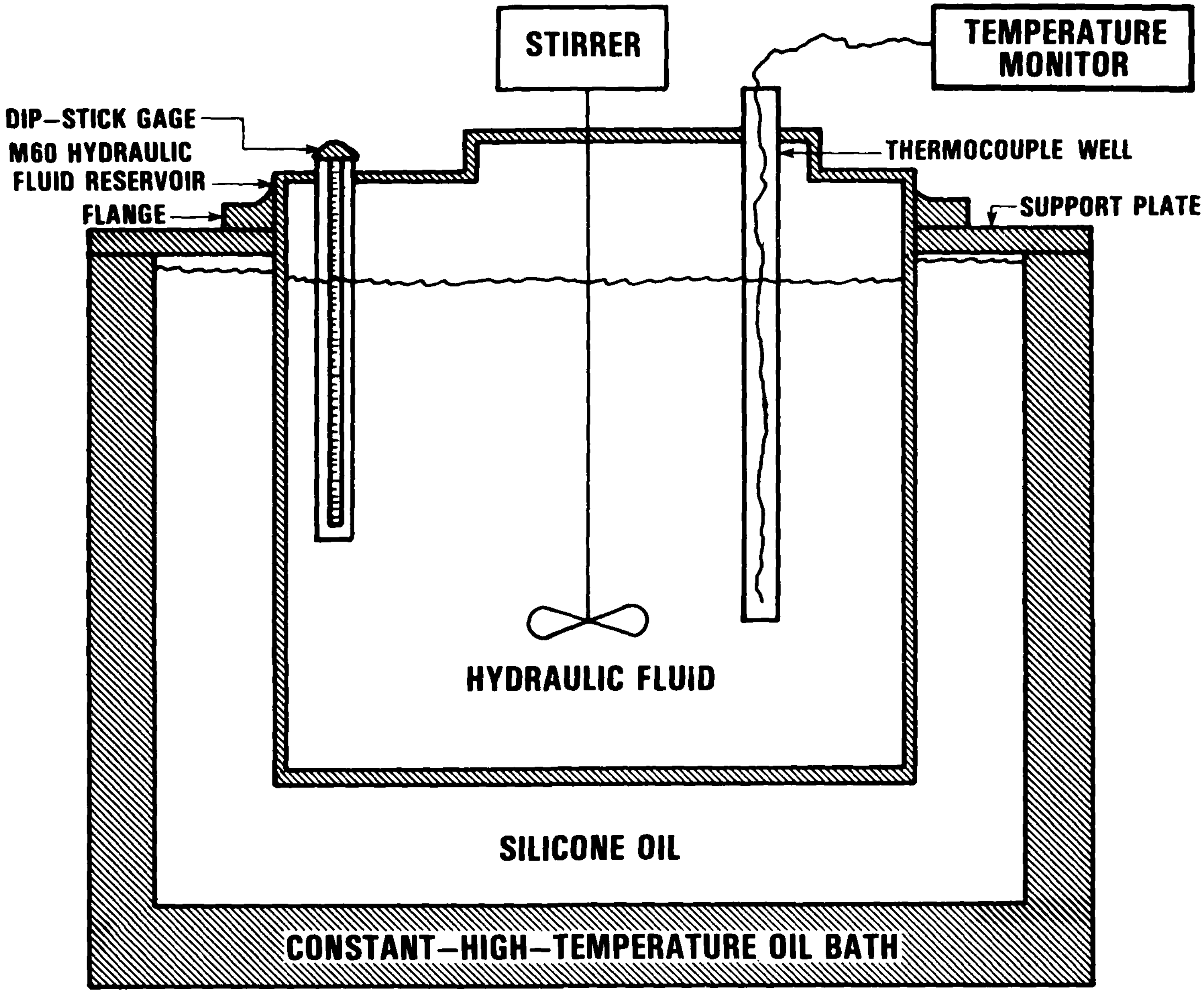
1 Military Specification MIL-H-6083 "Hydraulic Fluid, Petroleum Base, for Preservation and Operation."

2 Military Specification MIL-H-46170, "Hydraulic Fluid, Rust-Inhibited, Fire-Resistant, Synthetic Hydrocarbon Base."

3 James H. Conley and Martin E. Everett, STATUS OF THE DEVELOPMENT OF A NON-FLAMMABLE HYDRAULIC FLUID FOR ARMORED VEHICLES, MERADCOM Report 2362, Jun 82.

4 ASTM 972, "Evaporation Loss of Lubricating Greases and Oils."



Experimental Apparatus.

With the test apparatus, the evaporation tests were conducted at 160° F for 3 wk and an additional 3 wk at 200 °F. Fluids used in these tests were MIL-H-6083 fluid and CTFE fluid which has been chosen as the candidate base material for the non-flammable hydraulic fluid. The MIL-H-6083 fluid was selected as the reference fluid.

For the experiment, the following test procedure was applied to these tests: First, the reservoir was filled with the test fluid to the full mark (i.e., 3.17 gal) indicated on the dip-stick gage. The reservoir was then immersed in a silicone oil bath with a support plate. When the test temperature stabilized at 160 °F, the fluid level was measured again. The test was then continued for 3 wk. At the end of this test period, the fluid level was measured at the test temperature and also at room temperature. Then, an approximate 50-ml sample was collected from the reservoir. The viscosity of this sample was measured by the applicable ASTM method and the fluid condition was observed using the Infrared Spectrophotometer. At the same time, new fluid was evaluated by the same methods. For the follow-up test at 200 °F, new fluid was added to the reservoir to restore the fluid to the initial level before sample collection. The test procedure was the same as before, except that the test temperature was raised to 200 °F.

III. RESULTS OF TESTS

A summary of the evaporation test results is presented in Table 1. The result obtained for the CTFE fluid shows a 0.58-percent evaporation loss at 160 °F for the first 3-wk (504-h) test period and no further evaporation loss for the next 3-wk test period at 200 °F. In addition, the viscosity did not change during these test periods. Similarly, the OHT fluid showed a 0.56-percent evaporation loss. However, this loss occurred only at the high test temperature. The viscosity of this fluid was slightly decreased during the additional 3-wk test period. It appears the viscosity improver (V.I.) was degraded due to the high test temperature and/or shearing force. The Infrared Spectrophotometer also showed that the V.I improver changed in this test period. The specific gravity of both fluids did not change during the test period. However, the most significant result of these tests was that the evaporation loss of CTFE fluid was almost the same as that of the OHT fluid.

IV. DISCUSSION

The preliminary evaluation of the candidate fluid was conducted using the ASTM test method used in the previous study. The result showed that the candidate fluid did not meet the initially proposed Army target requirement for the non-flammable hydraulic fluid.[3] In a follow-up test, another assessment of volatility was made using the TGA method to provide more evidence. The test result indicated that the candidate fluid had a higher evaporation rate at a given temperature when compared to the reference OHT fluid. This result substantiated the relative evaporation loss indicated by the ASTM test method. Hence, these results can be considered the true evaporation loss of both fluids in specific open systems because both test methods used the air or purge gas to accelerate the evaporation process. However, the results obtained from the simulated service evaporation tests showed almost no evaporation loss in both fluids. The M60 hydraulic fluid reservoir used in these tests is considered a semi-opened system because a very small venting gap exists between the dip-stick gage cap and its tube. For all practical reasons, the hydraulic systems of armored vehicles can be considered a closed system.

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[3] James H. Conley and Martin E. Everett, STATUS OF THE DEVELOPMENT OF A NON-FLAMMABLE HYDRAULIC FLUID FOR ARMORED VEHICLES, MERADCOM Report 2362, Jun 82.

Table 1. Simulated Service Evaporation Test Results

Hydraulic Fluid	3 Weeks (504 h) at 160 °F					3 Weeks (504 h) at 200 °F					Total
	Viscosity at[a] 104 °F (cSt)		Specific Gravity[b] at 60 °F (g/cm³)		Δ Volume[c] (%)	Viscosity at 104 °F (cSt)		Specific Gravity at 60 °F (g/cm³)		Δ Volume (%)	Δ Volume
	Initial	Final	Initial	Final		Initial	Final	Initial	Final		
MIL-H-6083	14.5	14.5	0.881	0.881	0	14.5	14.2	0.881	—[d]	−0.56	−0.56
CTFE	2.8	2.8	1.871	—	−0.58	2.8	2.8	—	1.870	0	−0.58

[a] ASTM D-445, Kinematic Viscosity of Transparent and Opaque Liquids.

[b] ASTMD-2111, Specific Gravity of Halogenated Organic Solvents and Their Admixtures (Method B, specific gravity by means of a hydrometer). Standard deviation is approximately ± 0.005.

[c] The volume was measured at room temperature.

[d] Not determined.

'he simulated service evaporation test results were significantly different from those obtained in the two evious test methods. This can be explained best by noting the difference of opened and closed systems. In ened systems, the evaporation loss is directly related to the temperature, time, ratio of evaporation surface a to opening area, mechanical action, and ventilation (air, purge gas). In conditions of an opened system, por which escaped from the fluid surface cannot be recovered. Unlike the opened system, the closed system es not permit any evaporation loss to the outside. Once the vapor pressure has been established within the stem, the amount of fluid and vapor remain constant at a given temperature, since for every particle that aporates another condenses at the vapor-filled equilibrium.

In conjunction with the above facts, the test results showed that the M60 hydraulic fluid reservoir performed actically like a closed system, and the two previous tests represented opened systems. As a consequence of ese experimental differences, the results obtained from the two previous test methods showed no correlation those obtained in the simulated service evaporation tests. This simulated service evaporation test provided a alistic field environment.

The vapor pressure of the candidate fluid is about 4-mm Hg at 160 °F.[5] From the information available, it n be concluded that the hydraulic systems of armored vehicles generally operate at or below this mperature.[6] In addition, it is assumed that the actual maintenance interval with fluid replacement is shorter an 500 h.[7] Table 2 summarizes the results of evaporation losses by the different test methods.

Halocarbon Chlorofluoro Carbon Fluids and Lubricants, Halocarbon Products Corporation, 1979.

Test and Demonstration Report, M1 Hydraulic Heat Exchanger Evaluation, Report KZ-79-18322-023, Contract DAAK30-79-C-0004, Chrysler Defense, Inc., Nov 81.

Lubrication Order LO9-2350-232-12, "Tank, Combat, Full-Tracked: 152-mm Gun Launcher, M60A2," 28 Dec 73.

Table 2. Evaporation Loss by Test Methods

'est Method	Temperature (°F)	Period (h)	Evaporation Loss (%) CTFE	OHT	Proposed Army Target Requirement
STM	158	6	40.8	11.8	≤ 20% in 6 h
GA*	160-200	Straight run	5-12	0-2	N/A
imulated	160-200	1008	0.58	0.56	N/A

TGA results are shown in the appendix to this report.

V. CONCLUSIONS

on the results of the simulated service evaporation tests, it can be concluded that the high volatility of uid observed under standard test conditions in open and ventilated circumstances does not represent a t problem under conditions simulating the actual system environment. Although this system is semi- t can be considered closed for all practical purposes as far as fluid losses of CTFE are concerned. The uid losses of CTFE are comparable to the losses observed with the OHT fluid under identical condi- ce volatility never surfaced as a field problem for the OHT fluid, no problems would be expected for E fluid either.

APPENDIX

THERMOGRAVIMETRIC ANALYSIS (TGA) OF HYDRAULIC FLUID

mple:

MIL-H-6083 (OHT)

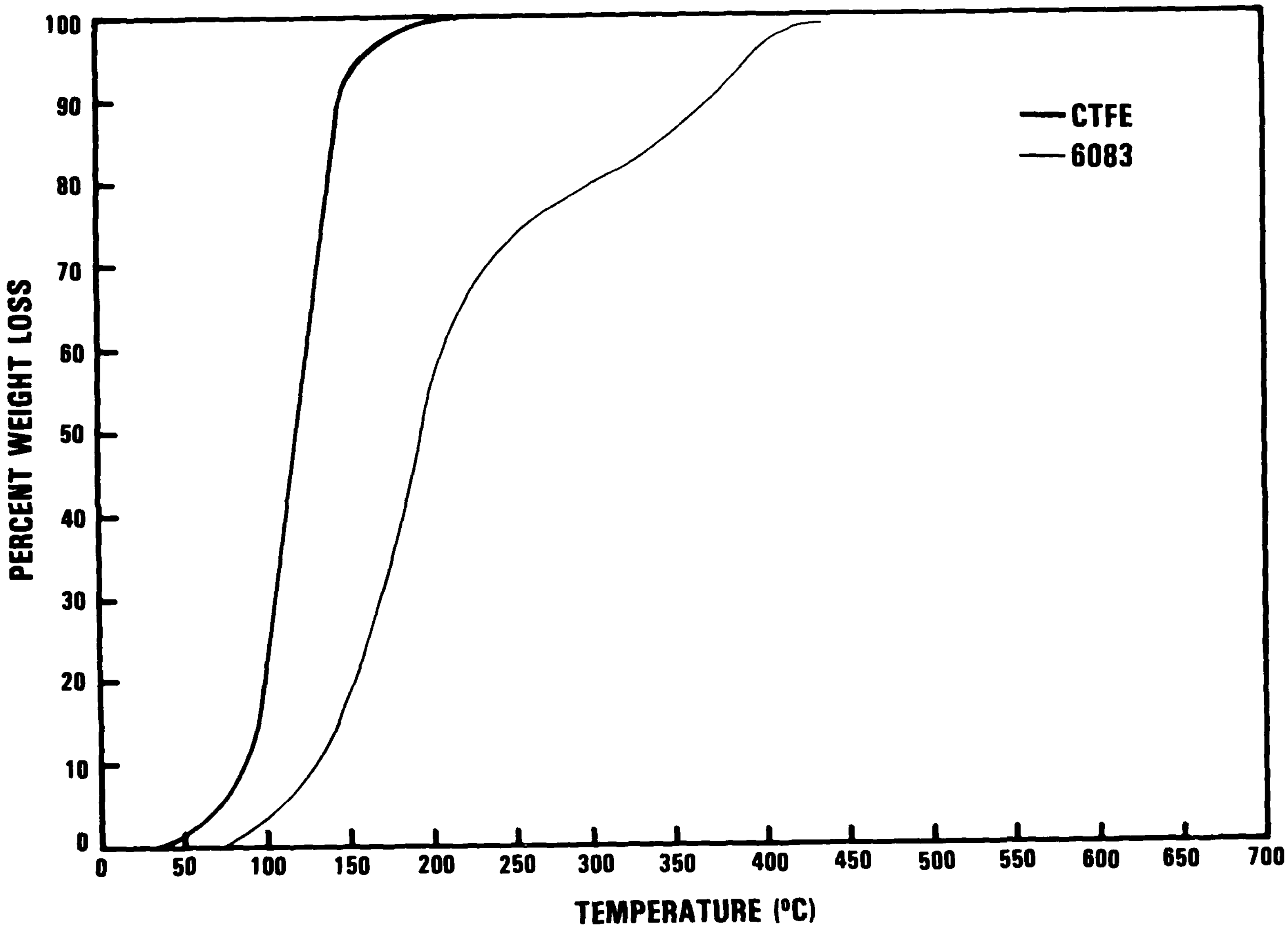
CTFE

st Conditions:

Heating Rate	10 °C/min
Atmosphere	N_2 @ 50 ml/min
Temperature Scale	50°/in
Span Adjust	20%/in
Suppression	0 mg
Time Constant	1 s
Thermocouple	chromel-alumel

Weight Loss of Hydraulic Fluid by TGA

ulic Fluid	Onset Temperature of Evaporation (°C)	50-Percent Weight Loss Over Temperature Range (°C)
TFE	45	45-120
HT	63	63-192.5



Thermogravimetric Analysis (TGA) of hydraulic fluids.

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